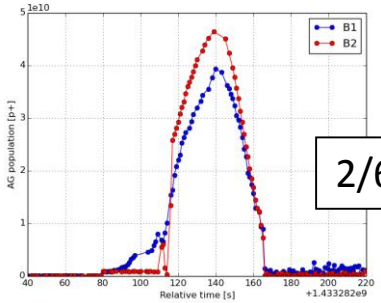
BSRA and Interlock BPM

T. Lefevre on behalf of the BI teams involved

Status of BSRA

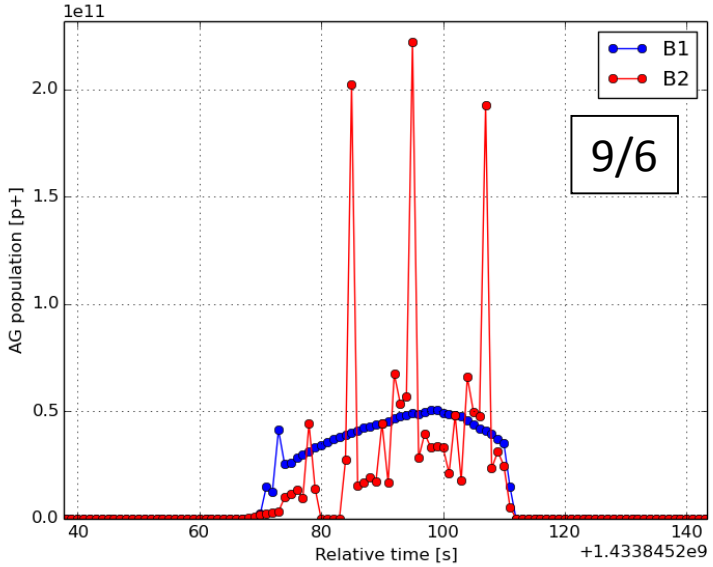
- BSRA calibrated and in operation since the beginning of May.
- Several issues solved so far:
  - Bug retrieving telegram information (beam energy);
    - Several crashes of the FESA server
  - PMT Gate protection recovery procedure : Switching off the PMT trigger as soon as the observed signal too high – Sending alarm and requiring a reset the gate to put the system back on
    - No data (PMT protection during Asynch. dump 19/5 @ 6.5 TeV
  - Zeroing of AG population after de-bunching due to Beam Presence Flag; now mitigated comparing to fast BCT reading :
    - Raw data are always fine – but display and logging depends on BPF : Asynch. dump 2/6 @ 6.5 TeV.
    - Should be discussed .. Would be better to provide data anyway (based on beam mode)
    - BPF is not a 'beam presence flag' but more a 'bunch presence flag'



2/6

BSRA data (so far)

- To be solved:
  - Threshold for display of calibrated data (now put to zero when below a threshold)
  - Unstable feedback for B2 high voltage
    - 2 x Asynch. dump 9/6 @ 6.5 TeV. Calibrated data OK for B1. Unstable voltage feedback for B2.
    - HV regulation loop have to be adjusted



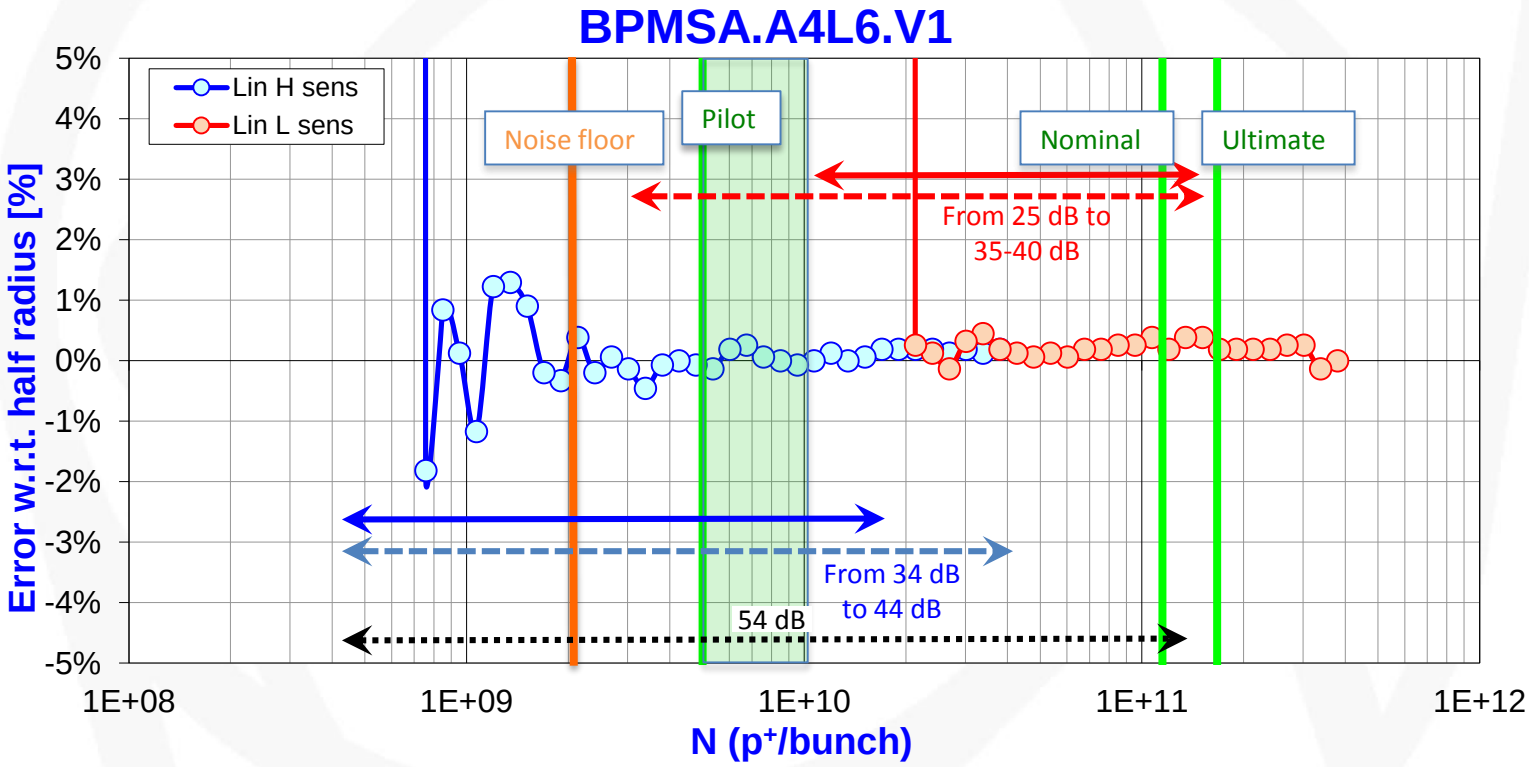
IR6 interlock BPM

- **BPMint modifications during LS1**
  - Hardware, firmware, software
- **Recommissioning, where are we ?**
- **List of past and present issues**
- **MPP related issue with Doublet bunches**
  - Injection protection
  - SIS interlock
  - BPM interlock

Hardware Modifications : LS1

- Improving the dynamic range of the BPM: Avoid dumping on false BPM readings when beam intensity decreases: Limiting signal reflection
  - Replaced shorted strip-lines with 50 Ω termination
  - Added absorptive filter at strip-line output (100 MHz)
- Better stability with thermal controlled racks
  - I will improve the long term reliability of the system
- Better monitoring/processing of Interlock data
  - Separated orbit and interlock functions (2 DABs)
  - Larger memory for interlock acquisition channel to store B/B data over 154turns
  - A daisy chain to trig all BPM channels synchronously

New dynamic ranges



	Before	Now
High Sens.	1.5E9 – 3E10	1.5E9 - >1.3E11

Dynamic range improved by more than 10dB

Low Sens.	*2E10 - > 2E11*	*1.5E10 - > 2E11*
Unchanged now but		*?? - > 2E11*

Issues so far

- 2 major hardware issues:
  - Integrator mezzanine replaced on BPMSI.B4L6.B2 (surface building) – spurious reading leading to large fluctuations in position readings that triggered several dumps
    - Effect, not permanent, took us some time to understand. Channels was masked for few days.
  - Faulty RF filter on BPMSX.A4R6.B1 – It dumped fills just before the TV show !! Implement for the occasion a dirty work around that triggered a SIS and dumped another time..no comment..
    - Problem was fixed the day after while accessing the tunnel

Issues so far

- Several software/firmware issues:
  - Observed a discrepancy of 0.5mm in between the limit set by MPP and the one re-calculated by FE
    - Error found in the software
  - New interlock Capture data (B/B position over the last 154 turns) not available due to an issue with the management of interrupts
    - Followed up with CO (Michel Arruat): New implementation of a programmable interrupt queue in encore driver level (CPU) is ready and tested.
    - Few firmware/software bugs corrected while testing the post-mortem buffer reading : Ready to deploy in new FESA release

Issues so far

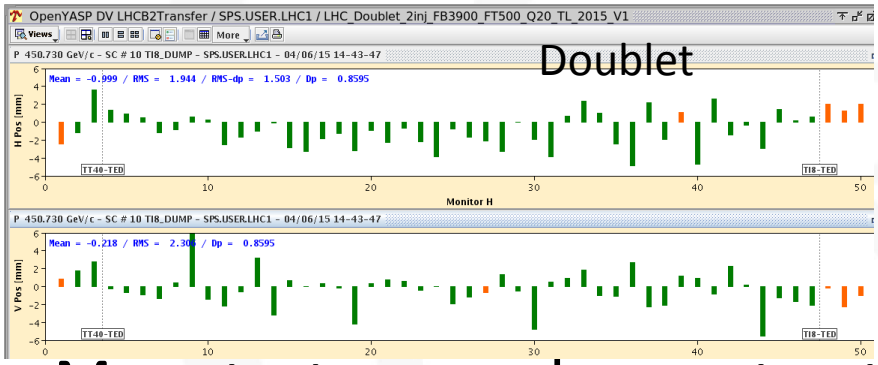
- More software/firmware issues:
  - Communication with Post-mortem DB tested and working in the lab..to be confirmed on Oper. crates
  - Issue with changing MCS settings is also now solved: to be deploy with new FESA release
  - Calibration procedure to be reviewed:
    - During run 1: the calibration procedure was set to' failed' only when the communication with the crate was down. Offset due to calibration changes were tolerated (due to the strong temperature dependence we had during run1)
    - We should review the procedure now and put back realistic limit in place between the requested and actual limits . . we will also monitor closely the drift of calibration values to detect hardware failure as early as possible

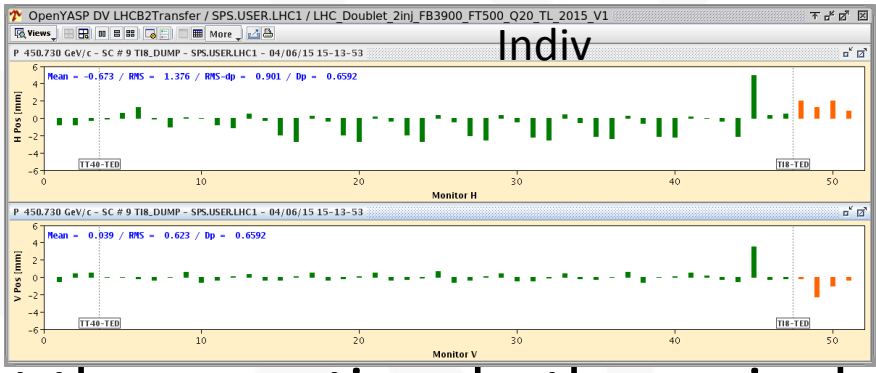
Issues with doublets

- From past test in SPS in fall 2014
  - Up to 2mm offset and larger errors/fluctuations (1-3mm) depending on the relative bunchlet intensity
- Injection protection - TL's BPM
  - Possible work around mixing both nominal and doublet bunches to validate the injection protection system, relying only on the nominal bunch position reading
- LHC orbit reading based on synchronous orbit reading on nominal bunches
  - We need to check any possible SIS interlocks to make sure they use the same philosophy
- IR6 interlock BPM
  - What do we do with position limit/threshold (relaxing them since we worked only at inj. Energy)
  - Increasing the count thresholds as well ?

Beam tests on SPS TLs and LHC

- Doublet attracted in SPS last week on TI8 TED





- More tests were done extracting at the same time both nominal and doublet bunches….we need to analyse the data and check carefully the BPM sensitivity ranges..
  - Train of 12 doublets followed by an Indiv : BPM in low sensitivity
  - Confirm a reproductible offset +3mm and spread in the measurement of max 0.5mm compared to Indiv
- Test in LHC…today ..
  - Measure offset both in low (nominal and doublets) and high (pilot and doublets) sensitivity
  - Using Head-Tail monitor to measure the orbit and trajectory differences between nominal and doublet
  - WCM and LDM measurements to check the bunchlet relative intensity

Conclusions

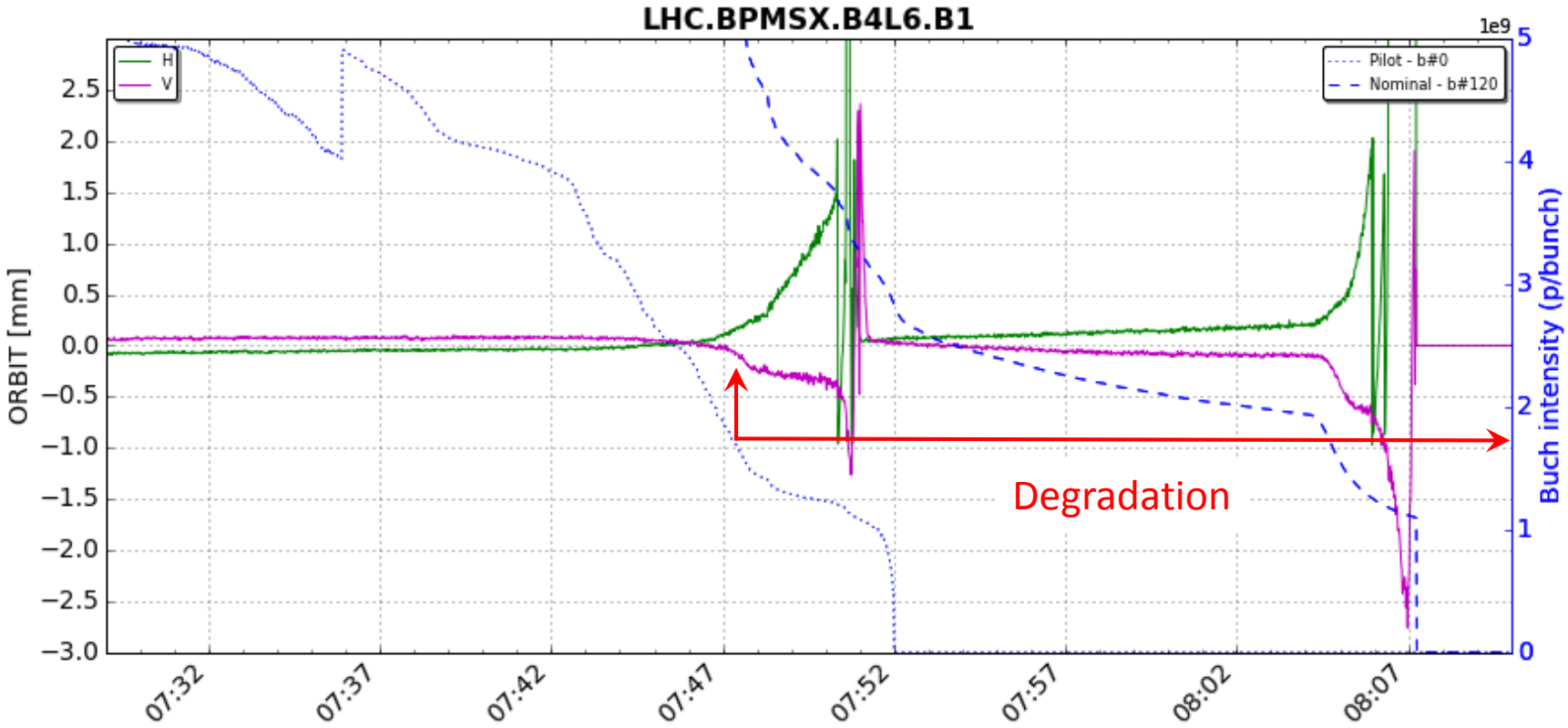
- LS1 Hardware modifications worked as expected
  - Larger dynamic range
  - Better triggering / synchronization of BPMs post-mortem data
  - Better long term stability with water-cooled racks
- Several issues during the first 2 months hardware and software bugs – hopefully a fully functional system after TS
- Interlock process was working reliably .... Validation to be redone with bunch train after TS
- Pending issue with Doublet bunches
  - Injection, Circulating beam, and interlock BPM
  - Need quantitative measurement now

Thanks

Spare Slides

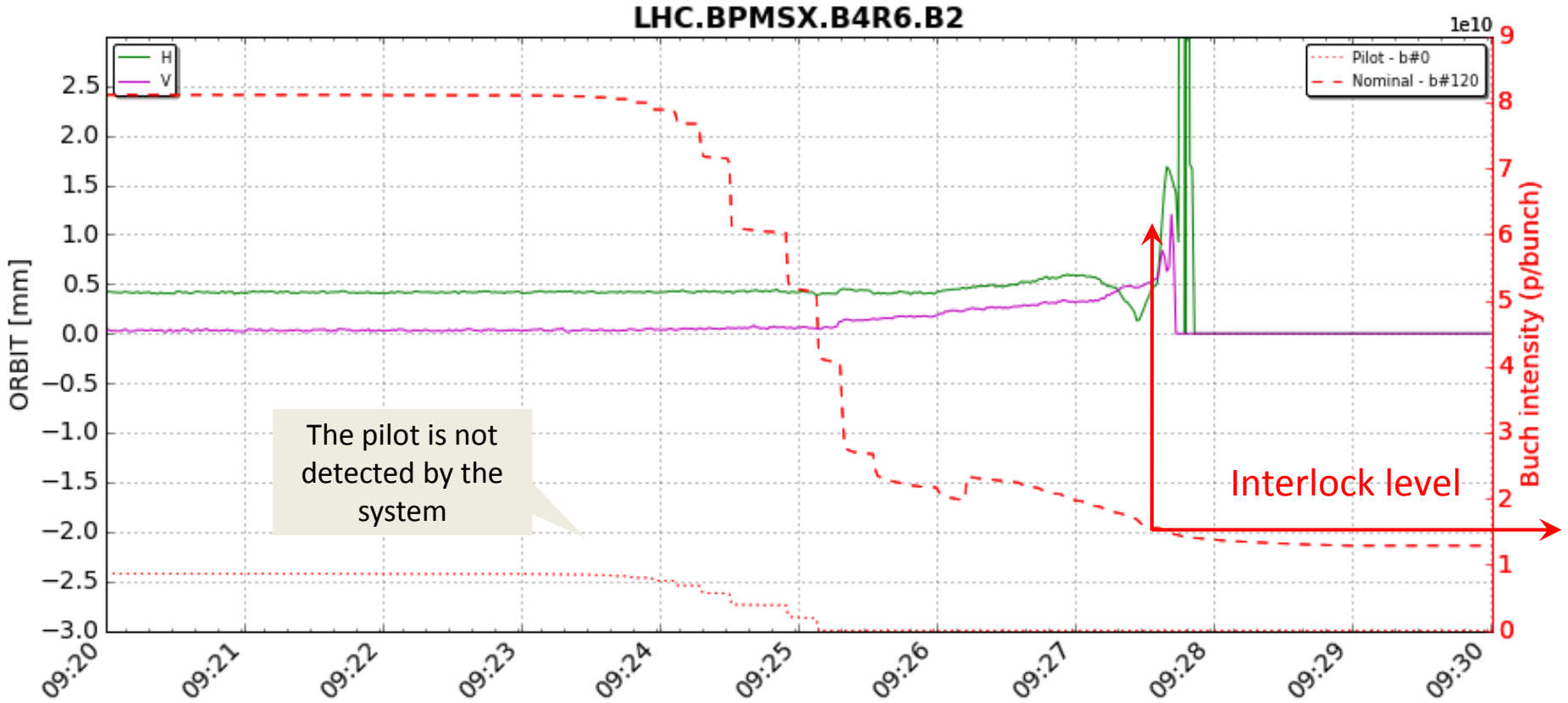
Re-commissioning

Scrapping one Pilot and one Nominal in **High sensitivity** mode



Re-commissioning

Scrapping one Pilot and one nominal in **low sensitivity** mode



Hardware changes during TS

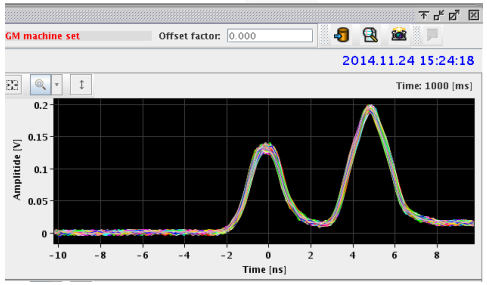
Do we keep the Dynamic ranges as such ?
Will it be a limitation during physic fills and scrubbing runs ?

- Ions-Ions or Ions-P fills using High Sensitivity Mode
  - Problem solved - Should not have any limitation in using any requested proton bunch intensity: however the limit may come now from the regular BPM system which do not have the extended dynamic range.
- P-P fills using Low Sensitivity Mode
  - Now at 1.5E10 but can go down if requested (need acces to UA)
  - Issue with Pilot bunch intensities : It should be seen by the BPM: What can be done to make sure that the Pilot bunches has always bunch population smaller than 5E9
    - Pilot Cleaning or Scrapping before injecting nominal bunch intensities ?

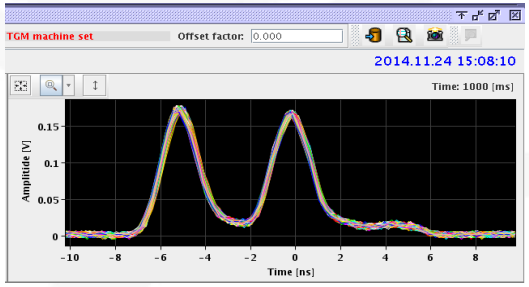
Doublet bunches

- Our electronic using amplitude to time normalization is sensitive to bunch spacing: Worst case .. 5ns..
- Simulations and lab tests were done earlier in 2014 to assess the effects
- Beam tests in SPS using Doublet bunches in fall 2014

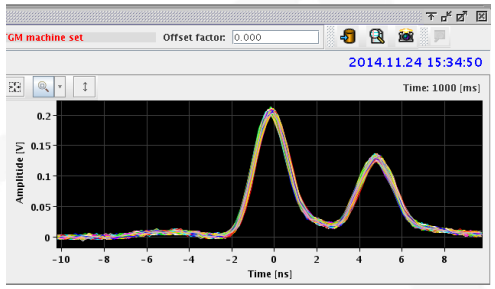
Unbalanced -/+



Balanced



Unbalanced +/-



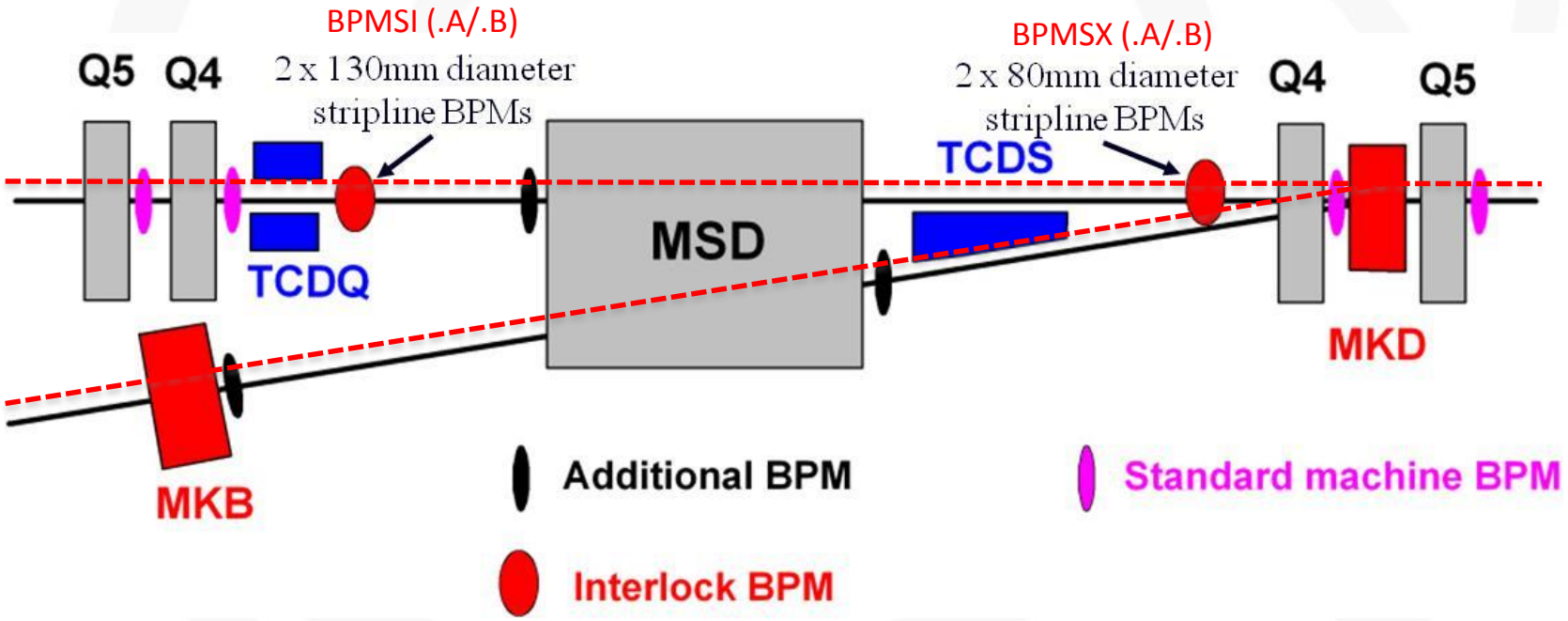
Beam tests on SPS

- Test done on 3 button BPMs 'BPMB': 513, 515 and 519
  - BPMB aperture 83mm : 34mm Button diameter
  - Resolution in b/b mode: 90um/bin
- Using a train of bunches with 25ns spacing
- Always acquiring reference measurements with nominal bunches (b/b over 1000 turns)
- Switching to Doublets
  - Tests at both injection and flat top
  - Tests with 'centered' beam and using orbit bump at flat bottom
  - Comparing the orbit offset with respect to nominal bunches (extrapolated for all BPMs in LHC) and measuring the b/b fluctuations/noises relevant for LHC interlock BPMs

Conclusions of the tests

- Offset similar to the one simulated has been confirmed on SPS
  - Up to 2mm orbit offset observed using doublet bunches
  - It can be measured and compensated for as a fixed offset
- B/B fluctuations are enhanced using Doublets from 1 to 3mm
  - A fraction of it can be linked to the Doublet beams themselves being instable
- No observable change for different bunch length
  - Bunch length fluctuations are almost suppressed in the electronic by the 70MHz input filter
- Unbalanced doublet affects the measurements both the offset and the fluctuation/noise
  - Unbalanced doublet -/+ showed smaller fluctuations and smaller offset: Is that an option ?
- Can we tolerate offsets/fluctuations almost doubling the current limits

Dump Channel



The main aim of these BPMs is to avoid large orbit offsets leading to high losses on the septum protection during a dump

Interlocked BPMs

- Strip line pick-ups installed in IR6 just after Q4 (BPMSX was BPMSA) and just before the TCDQ (BPMSI was BPMSB)
- Prevent beam on TCDS
- Acquisition is based on the LHC BPM design with dedicated firmware
- Two operational ranges used (high and low sensitivity modes)

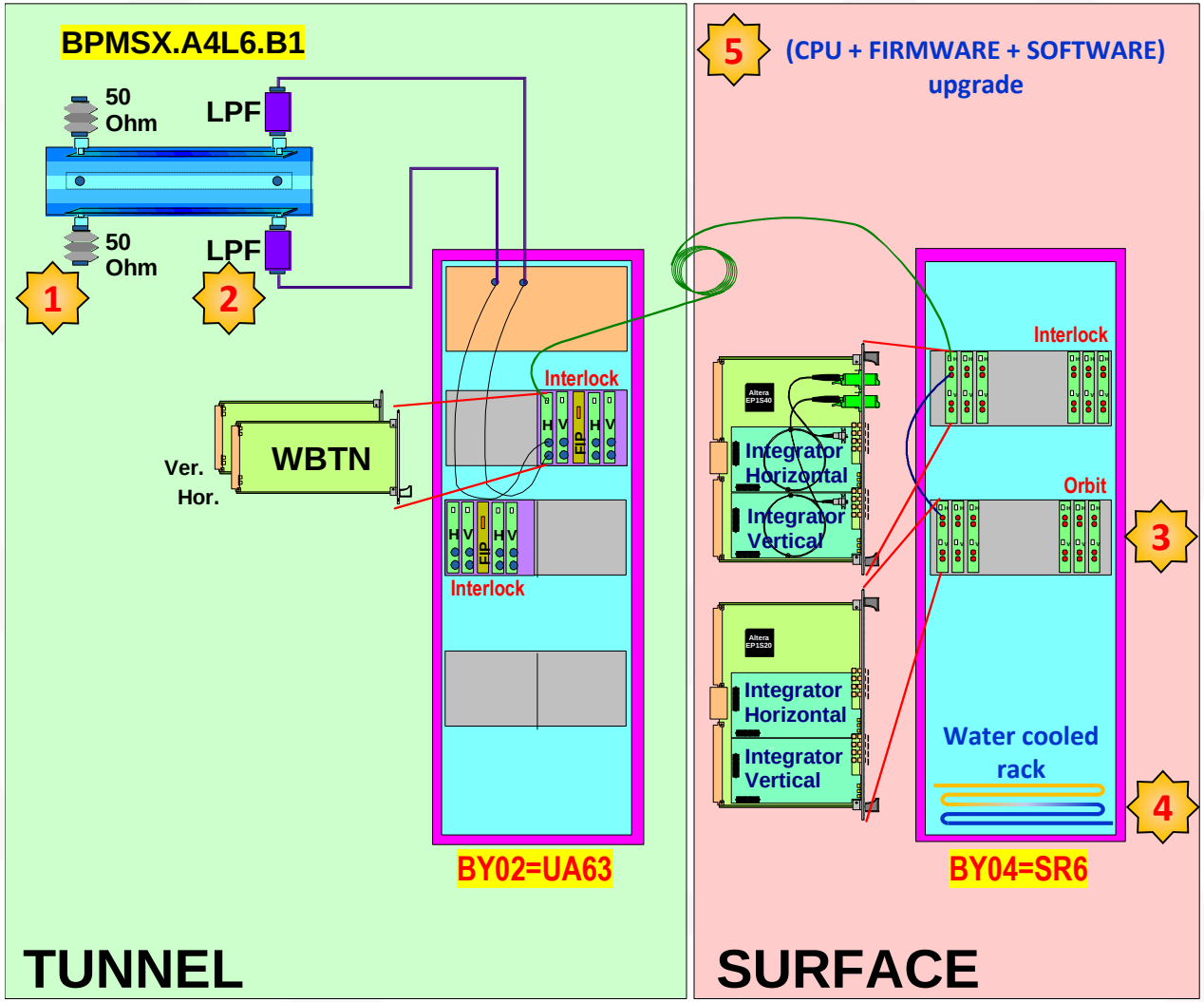
Interlock Mechanism

- Two separate trigger logics
  - 70 reading in the last 100 turns out of limits (a single bunch can trigger the dump)
  - 250 reading in the last 10 turns out of limits (response to fast orbit changes)
- Limits set to ~±3mm
- The whole chain from readout to beam dump trigger is in hardware (and firmware)
- Interlock signal connected to a maskable channel of the BIS

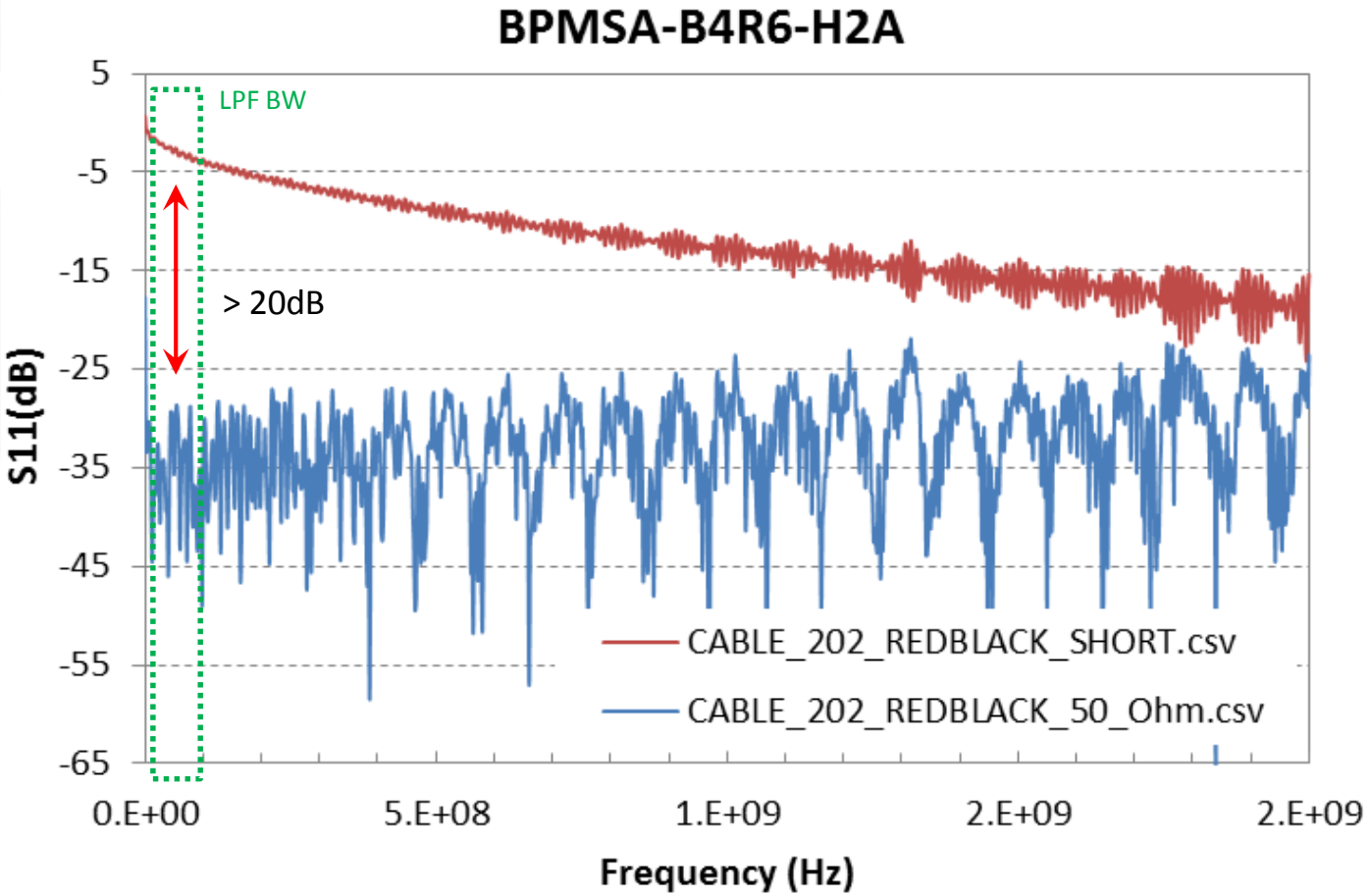
New BPM-int setup

The BPMs have been renamed (LHC-BP-EC-0002)

The Interlock and orbit systems have been separated

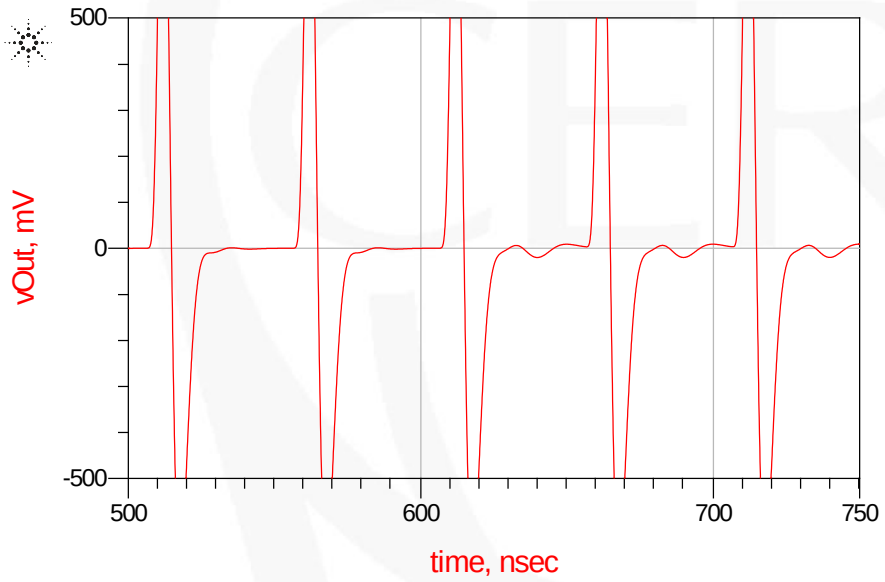


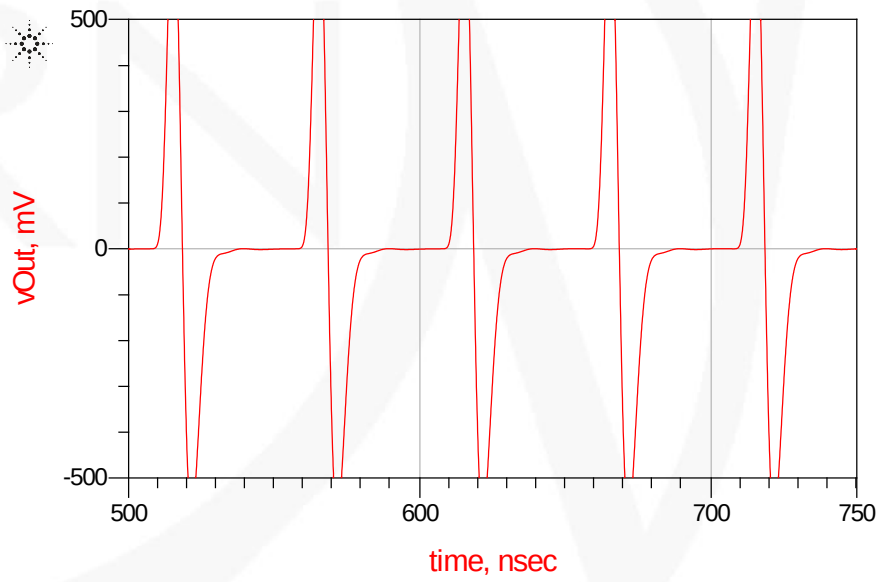
BPMs Reflections



More than a factor 10 improvement on the Pick-up

Reflections in time domain

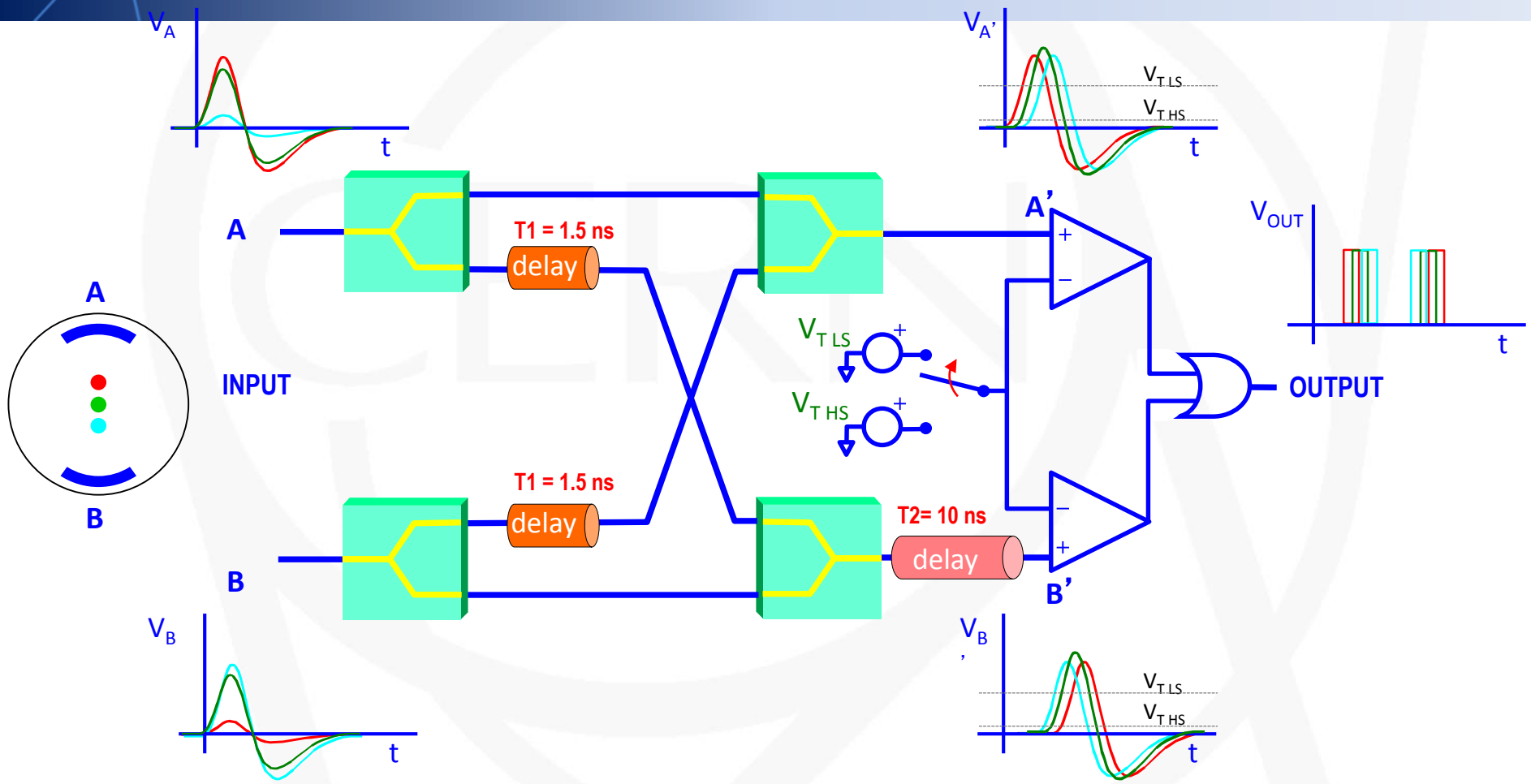




Shorted strip-lines reflections
Measurement: -27 dB
Simulation: -34 dB

Terminated strip-lines with LPF:
Simulations: <-46 dB

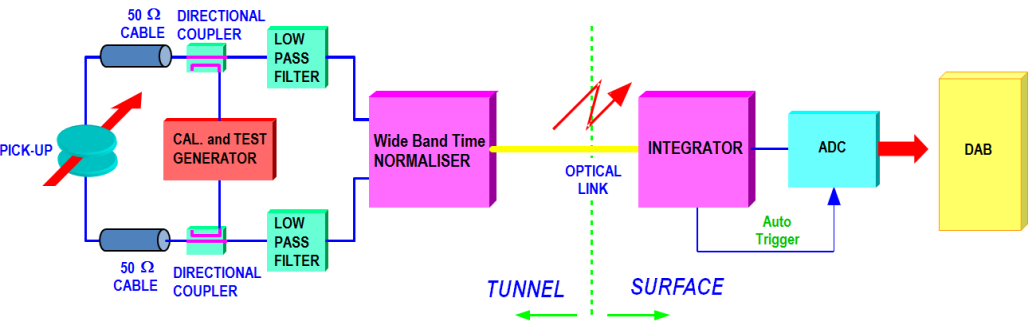
The WBTN principle



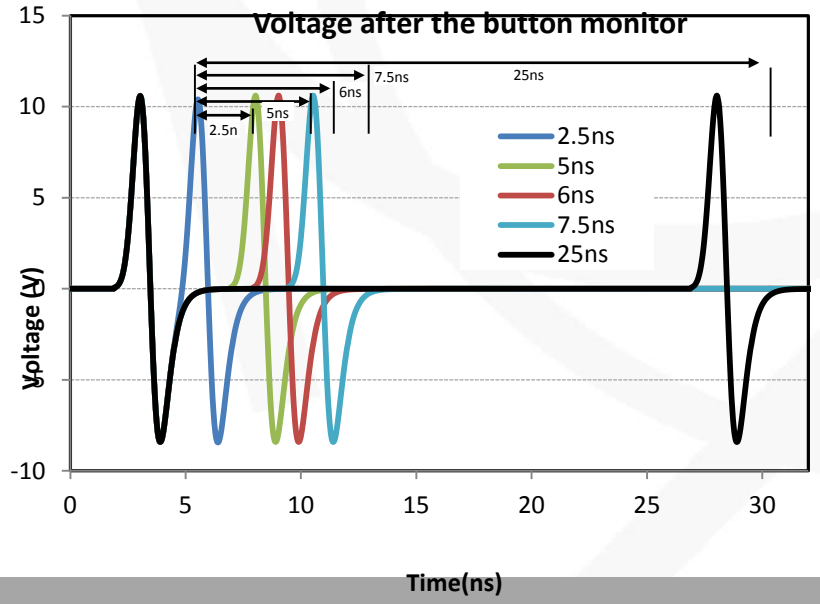
Amplitude modulation

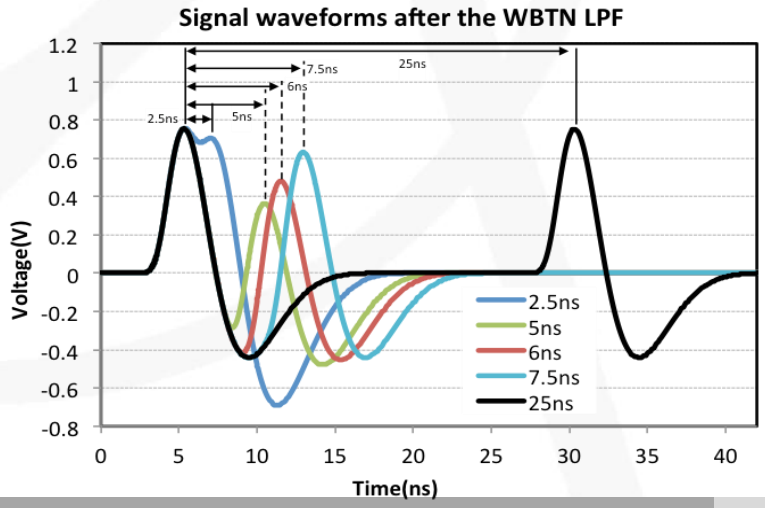
Time modulation

LHC BPM - WBTN



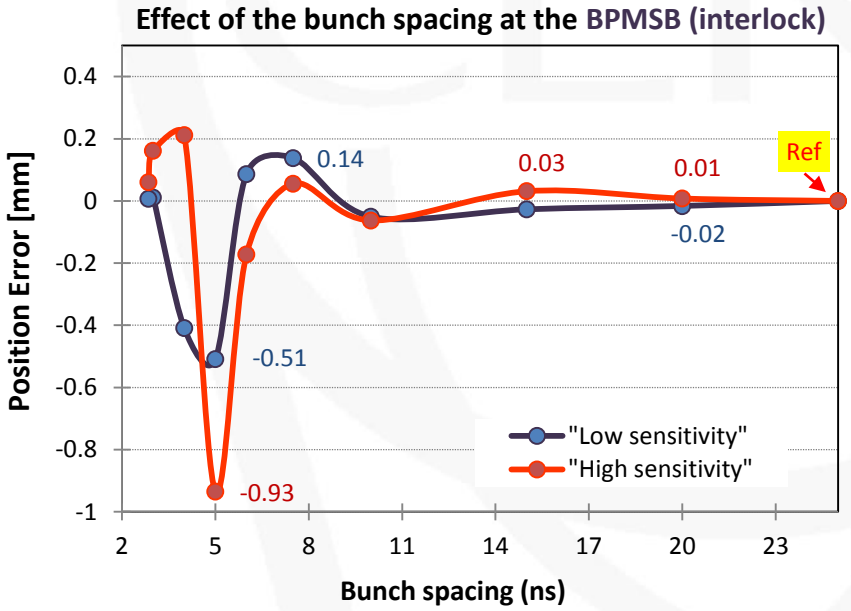
- Amplitude to Time conversion
- 70MHz LPF at the input of the electronic (bunch length independent)
- Depending on the bunch spacing , the signal will overlap in different ways.
- The system will provide a single measurement for bunches which are spaced by less than ~20ns.

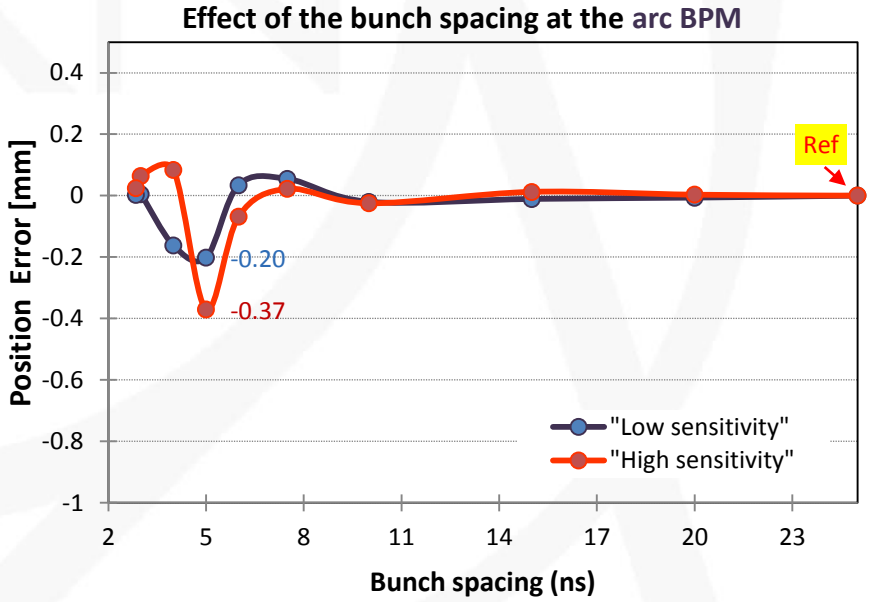




Scrubbing doublets

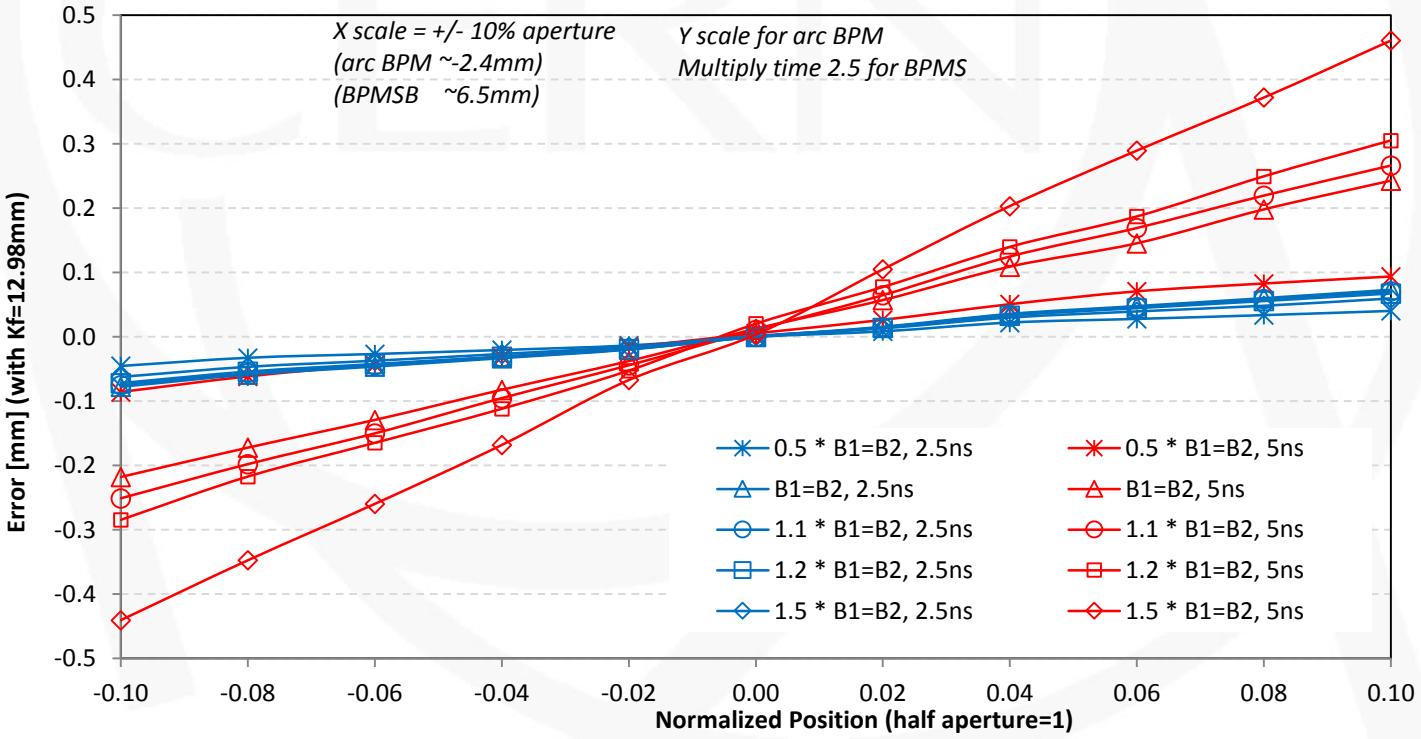
Beam “simulator” tests (beam signal replaced by pulse generator)
May be possible to test on SPS with beam





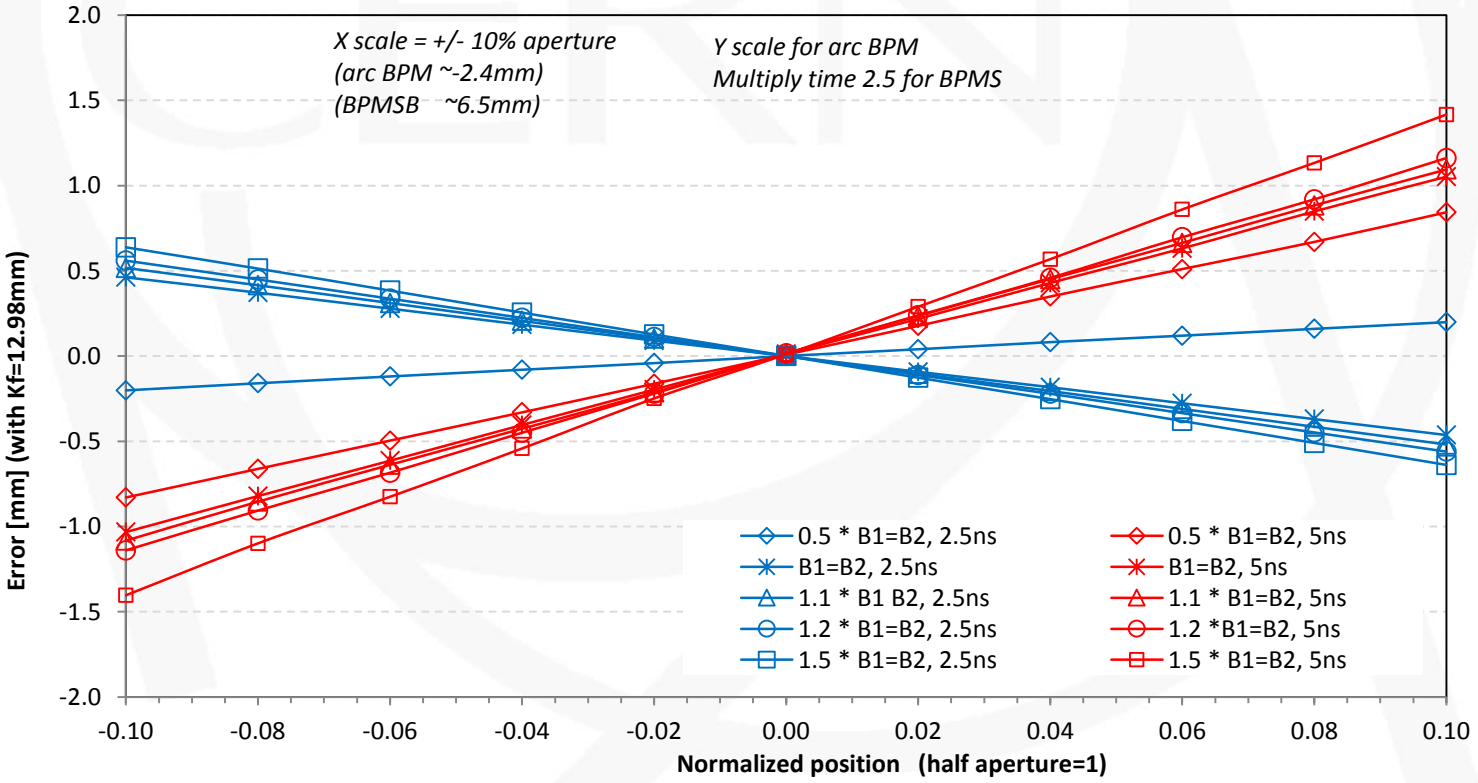
Doublets simulations 1

Bunch 1 and bunch 2 with same position



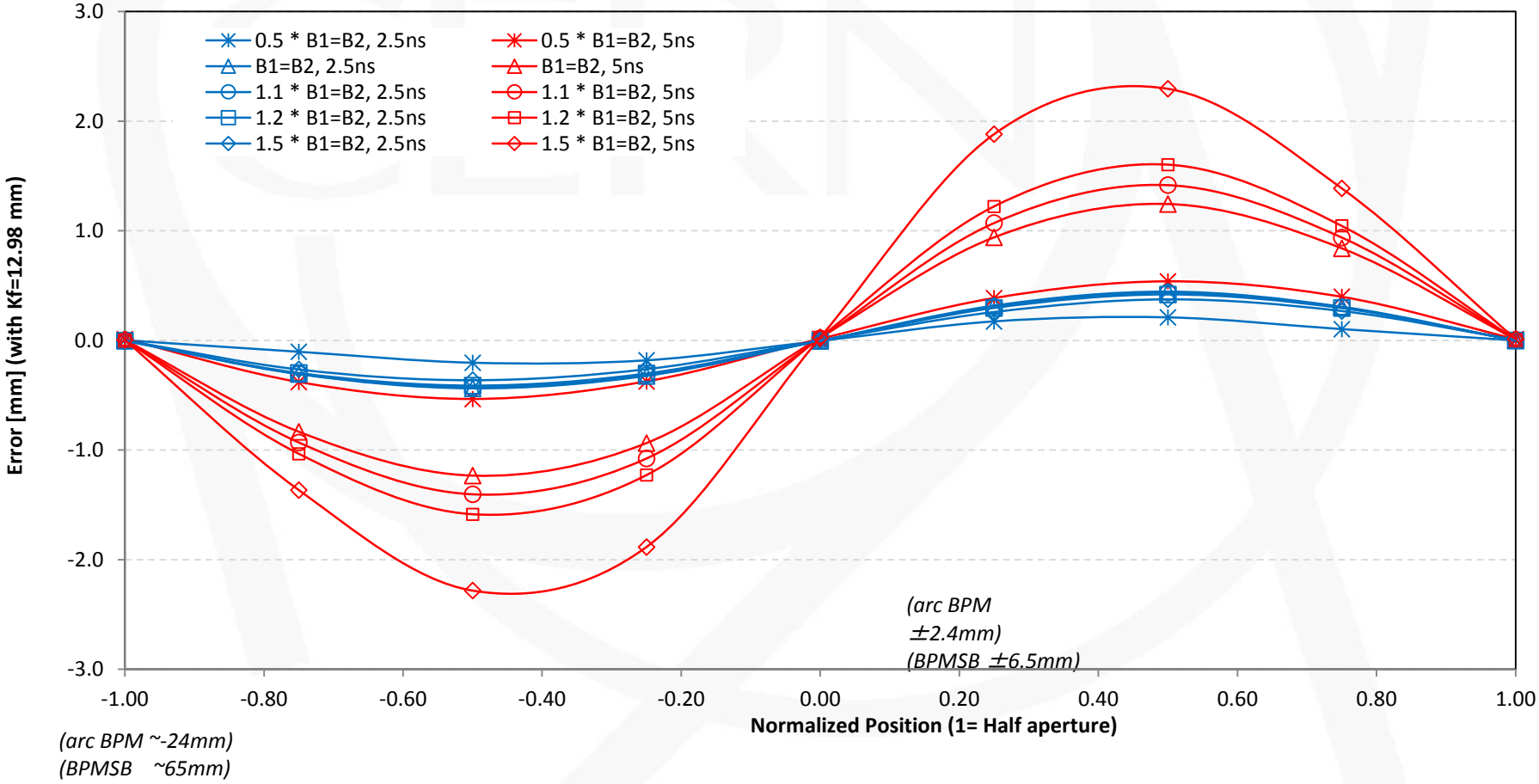
Doublets simulations 2

Bunch 2 always centred



Simulations with Pspice

- **Bunch 1 and 2 can have different intensities : '(Un)Balanced Doublet'**
- Normalizer model circuit and signals are "ideal"
- Realistic Bunch length

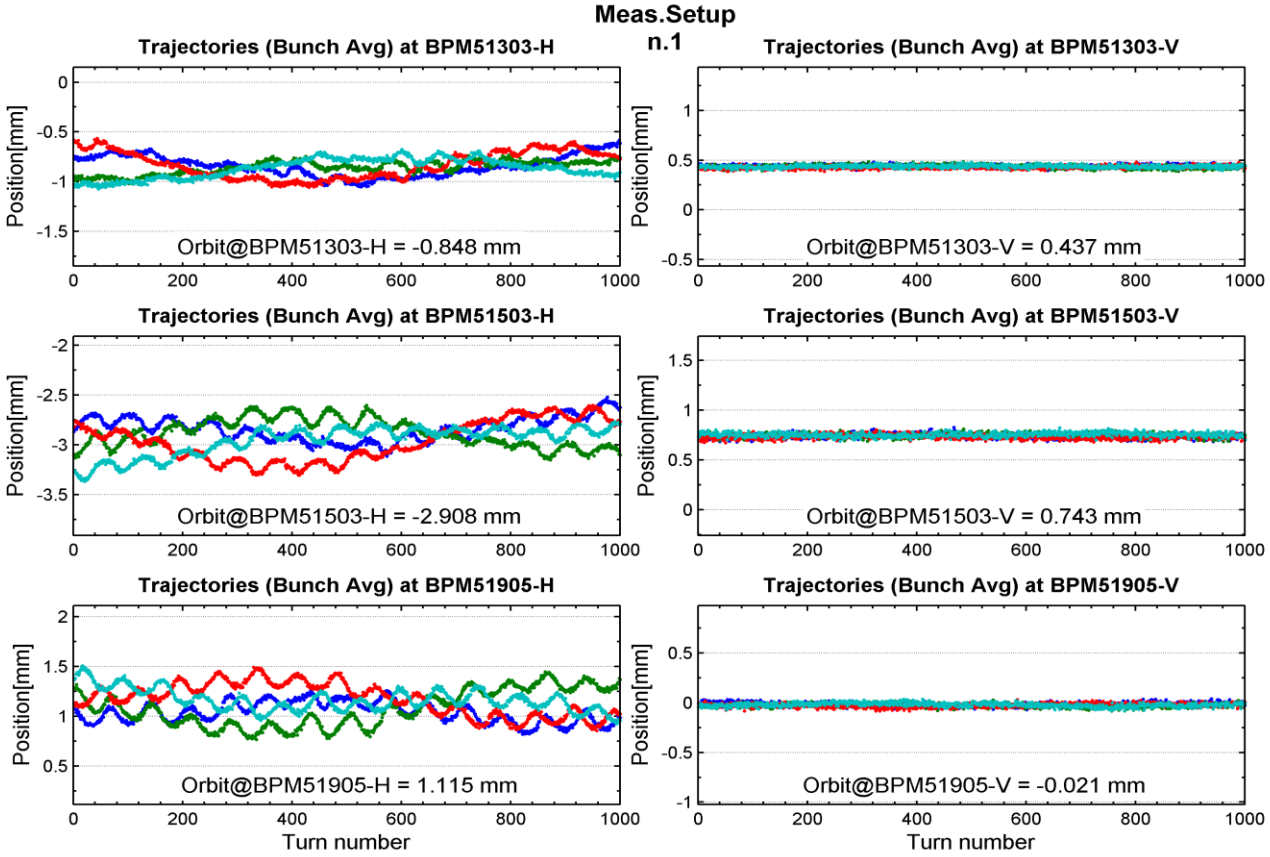


(arc BPM ~-24mm)
(BPMSB ~65mm)

Note : Half Aperture of arc BPM = 24mm
Half Aperture of BPMSB = 65 mm

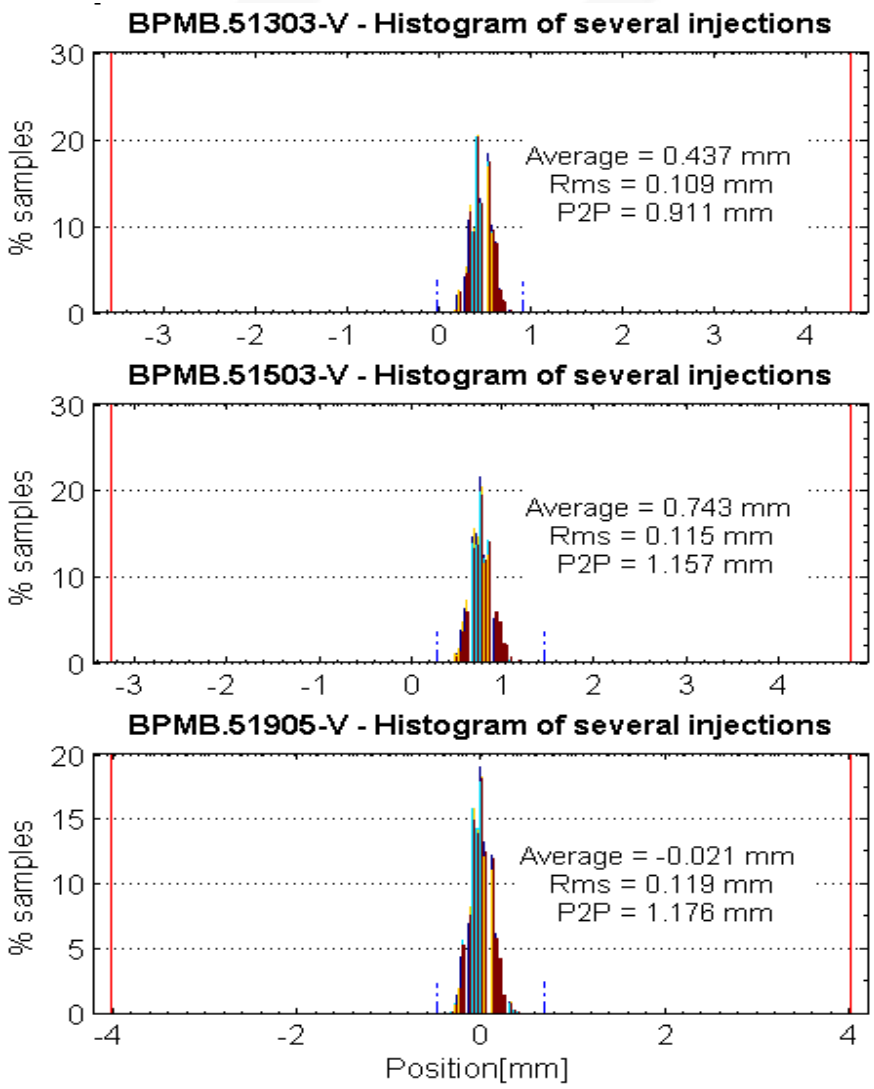
Nominal bunches at injection

- At 26GeV - 72 nominal bunches @ 25ns
- 1000 turns acquisition 560ms after injection – Turn-by turn data averaging all bunches over one turn



- *Oscillations/variations quite strong in horizontal plane*
- *Presenting only results in the vertical plane to get better resolution*

Nominal bunches at injection



- At 26GeV – 72 nominal bunches @ 25ns
- Histogram of B/B positions over 1000 turns
- BPM in Low sensitivity

	BPMB.51303-V			BPMB.51503-V			BPMB.51905-V		
	Orbit	Rms	P2P	Orbit	Rms	P2P	Orbit	Rms	P2P
Inj. N.1	0.443	0.107	0.864	0.740	0.107	0.915	-0.015	0.116	1.029
Inj. N.2	0.436	0.109	0.864	0.748	0.117	0.915	-0.024	0.120	1.127
Inj. N.3	0.430	0.110	0.815	0.732	0.113	0.867	-0.024	0.119	1.128
Inj. N.4	0.438	0.110	0.911	0.754	0.121	1.157	-0.020	0.120	1.078
AVERAGE	0.437	0.109	0.863	0.743	0.115	0.963	-0.021	0.119	1.090

- *Good fill to fill orbit stability of +/-10um*
- *b/b r.m.s variation around 100um (close to resolution limit of 90um)*
- *peak to peak variation over 1000 turns around 1mm (due to few bunches with larger variation)*

Nominal bunches at injection

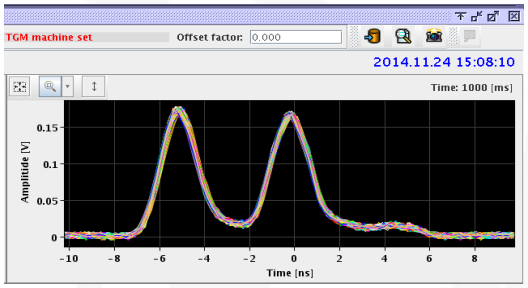
- At 26GeV – 72 nominal bunches @ 25ns
- Several measurement taken during the day over 6h period

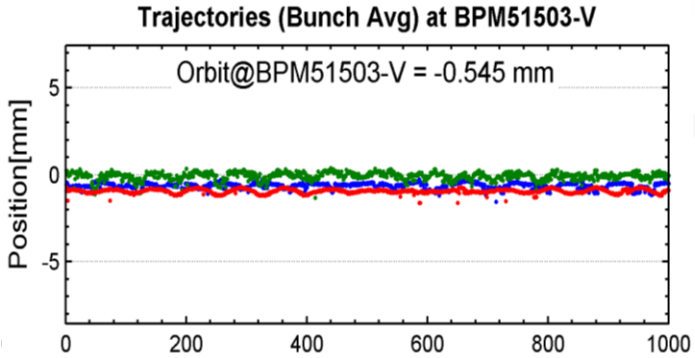
	Orbit during Setup #1	Orbit during Setup #4	Observed drift
BPMB.51303-V	0.437 mm	0.467 mm	0.030 mm
BPMB.51503-V	0.743 mm	0.755 mm	0.012 mm
BPMB.51905-V	-0.021 mm	-0.008 mm	-0.013 mm

Good reproducibility with very small orbit drift observed over 6h !

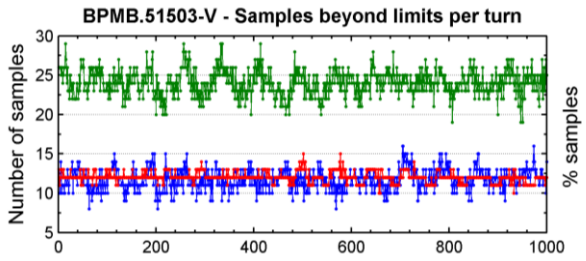
Doublet bunches at injection

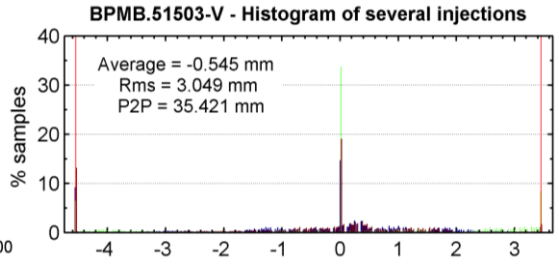
- At 26GeV – 72 Doublet bunches @ 25ns
- 1000 turns acquisition 560ms after injection
- BPM in Low sensitivity





	BPMB.51303-V			BPMB.51503-V			BPMB.51905-V		
	Orbit	Rms	P2P	Orbit	Rms	P2P	Orbit	Rms	P2P
Inj. N.1	-0.597	2.702	**35.225**	-0.628	2.804	**34.995**	-2.557	4.709	**32.387**
Inj. N.2	-2.893	7.277	**35.726**	-0.068	3.129	**35.201**	-2.274	6.683	**28.255**
Inj. N.3	-0.434	2.590	**35.140**	-0.939	3.138	**28.878**	-1.907	4.220	**33.254**
AVERAGE	-1.308	4.190	**35.364**	-0.545	3.023	**33.025**	-2.246	5.204	**31.299**



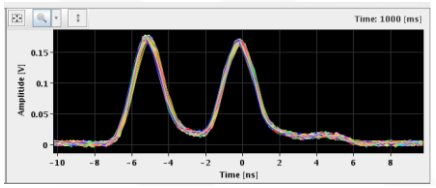


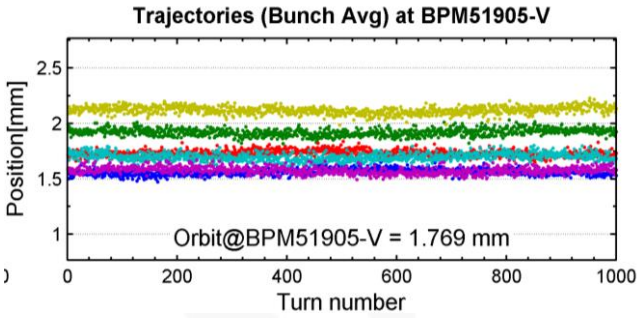
- *Not reproducible Orbit offset*
- *Very large r.m.s b/b variation*
- *Out of range Peak to peak variation*
- *High number of bunches measured outside the position limit (+/-4mm)*

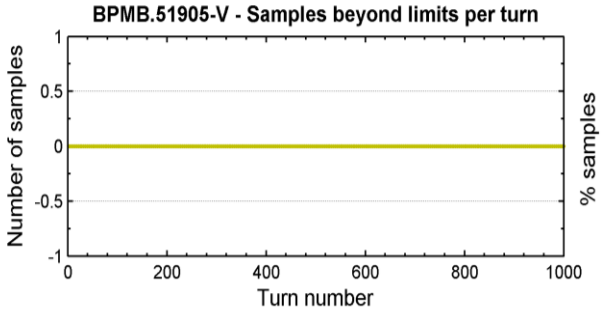
With doublet bunches - Low sensitivity mode is not functioning anymore – (pulse length issue)

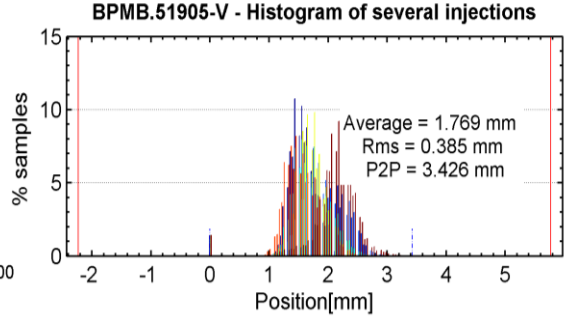
Doublet bunches at injection

- At 26GeV – 72 Doublet bunches @ 25ns
- 1000 turns acquisition 560ms after injection
- BPM in High sensitivity









	BPMB.51303-V			BPMB.51503-V			BPMB.51905-V		
	Orbit	Rms	P2P	Orbit	Rms	P2P	Orbit	Rms	P2P
Inj. N.1	1.664	0.185	2.434	1.384	0.156	1.114	1.563	0.272	2.517
Inj. N.2	1.773	0.208	2.728	1.580	0.213	1.649	1.922	0.405	3.072
Inj. N.3	1.664	0.175	1.309	1.419	0.180	1.358	1.732	0.289	2.147
Inj. N.4	1.709	0.186	2.434	1.455	0.172	1.405	1.700	0.308	2.719
Inj. N.5	1.595	0.163	1.308	1.319	0.164	1.259	1.577	0.291	1.996
Inj. N.6	1.839	0.221	1.841	1.732	0.234	1.940	2.120	0.392	3.426
AVERAGE	1.707	0.190	2.009	1.481	0.186	1.454	1.769	0.326	2.646

- *Reproducible Orbit offset*
- *(Reasonable) r.m.s b/b variation (0.3mm)*
- *No bunch measured outside the position limit (+/-4mm)*

Open question – **What is due to electronic** / what is linked to quality of doublet beam ?

Doublet bunches at injection

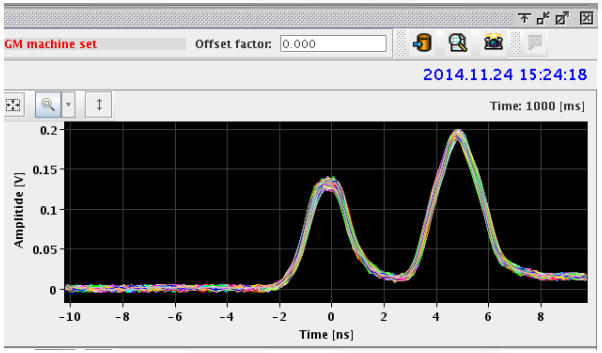
- At 26GeV – 72 Doublet bunches @ 25ns
- 1000 turns acquisition 560ms after injection
- BPM in High sensitivity

	V. Orbit during Nominal	V. Orbit during Doublet	Drift due to doublet (balanced) beam
BPMB.51303-V	0.467 mm	1.707 mm	1.240 mm
BPMB.51503-V	0.755 mm	1.481 mm	0.726 mm
BPMB.51905-V	-0.008 mm	1.769 mm	1.777 mm

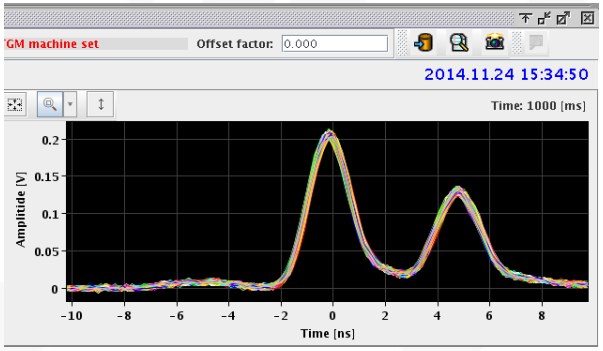
- *Averaged offset of 1.1mm with large variation for the different pick-up (not clear why but BPM519 electronic is noisier)*
- *b/b variation larger up to 3mm (factor 3 more than with nominal bunches)*

Unbalanced Doublet bunches

- At 26GeV – 72 Doublet bunches @ 25ns
- 1000 turns acquisition 560ms after injection
- BPM in High sensitivity
- Tests done with and without vertical bump in 515



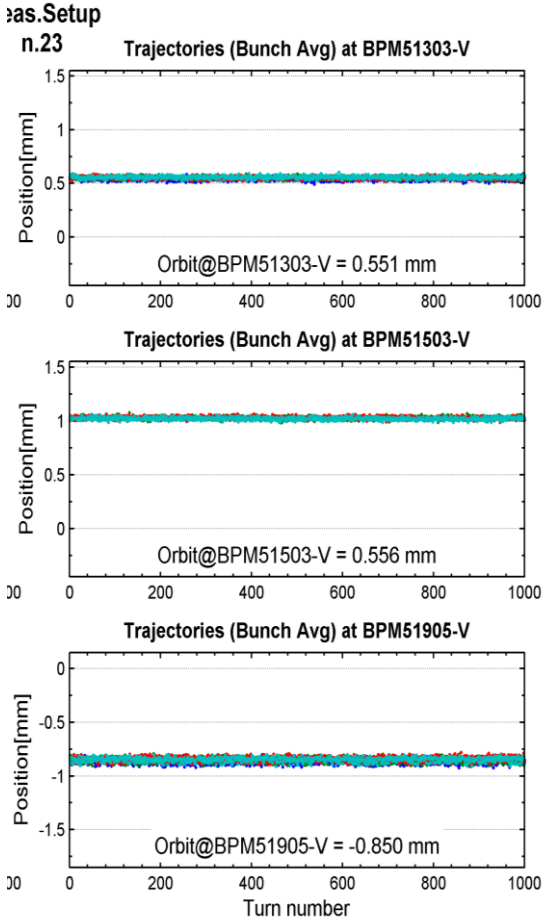
Unbalanced -/+



Unbalanced +/-

Nominal bunches at Flat top

- At 450GeV – 72 nominal bunches @ 25ns
- 1000 turns acquisition 28.3s after injection
- BPM in Low sensitivity



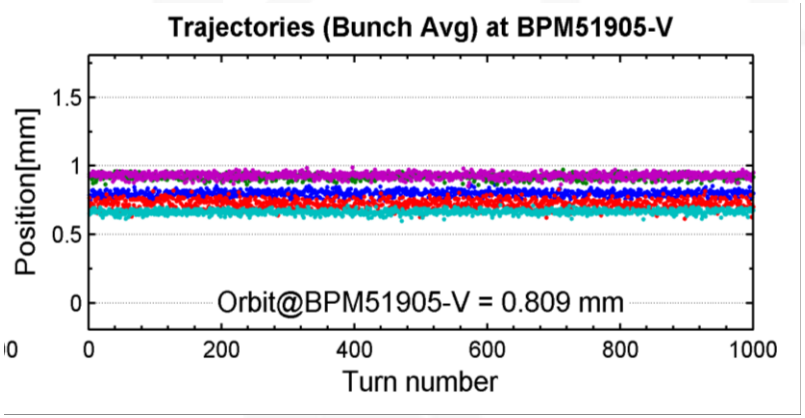
	BPMB.51303-V			BPMB.51503-V			BPMB.51905-V		
	Orbit	Rms	P2P	Orbit	Rms	P2P	Orbit	Rms	P2P
Inj.N.1	0.539	0.112	0.912	1.029	0.106	1.117	-0.863	0.142	1.117
Inj.N.2	0.553	0.109	0.912	1.031	0.106	0.966	-0.851	0.143	1.068
Inj.N.3	0.554	0.112	0.912	1.033	0.108	0.966	-0.839	0.148	1.068
Inj.N.4	0.557	0.111	1.009	1.024	0.108	0.966	-0.847	0.148	1.165
AVERAGE	0.551	0.111	0.936	1.029	0.107	0.966	-0.85	0.145	1.105

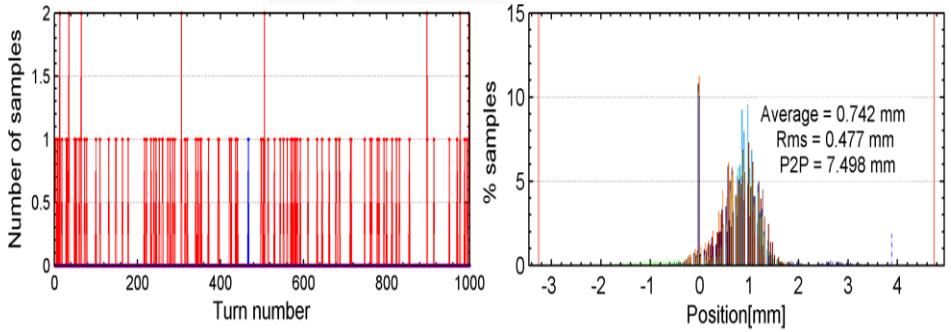
- *Good to fill orbit stability of +/-10um*
- *b/b r.m.s variation around 100um (close to resolution)*
- *peak to peak variation over 1000 turns around 1mm (few bunches)*

Doublet bunches at Flat top

- At 450GeV – 72 Doublet bunches @ 25ns
- 1000 turns acquisition 28.3s after injection
- BPM in High Sensitivity

	BPMB.51303-V			BPMB.51503-V			BPMB.51905-V		
	Orbit	Rms	P2P	Orbit	Rms	P2P	Orbit	Rms	P2P
Inj. N.1	1.750	0.325	2.184	1.867	0.428	4.014	0.800	0.526	4.677
Inj. N.2	1.862	0.184	1.649	2.007	0.182	1.654	0.922	0.257	2.172
Inj. N.3	1.790	0.362	6.610	1.975	0.448	8.830	0.725	0.581	6.081
Inj. N.4	1.705	0.288	2.532	1.798	0.288	2.090	0.666	0.365	2.618
Inj. N.5	1.858	0.248	2.728	1.995	0.235	1.607	0.93	0.301	1.979
AVERAGE	1.793	0.281	3.140	1.928	0.316	3.639	0.809	0.406	3.505

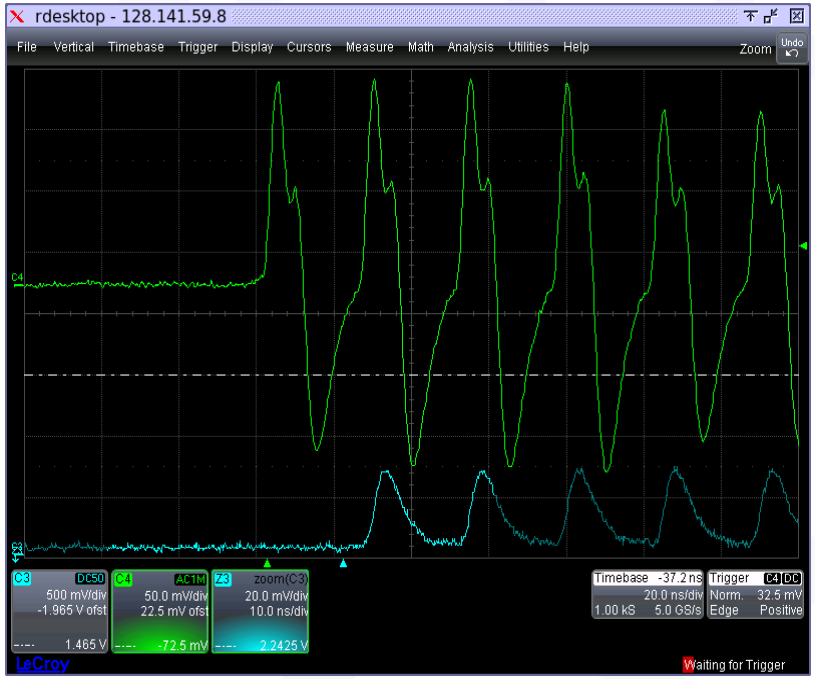


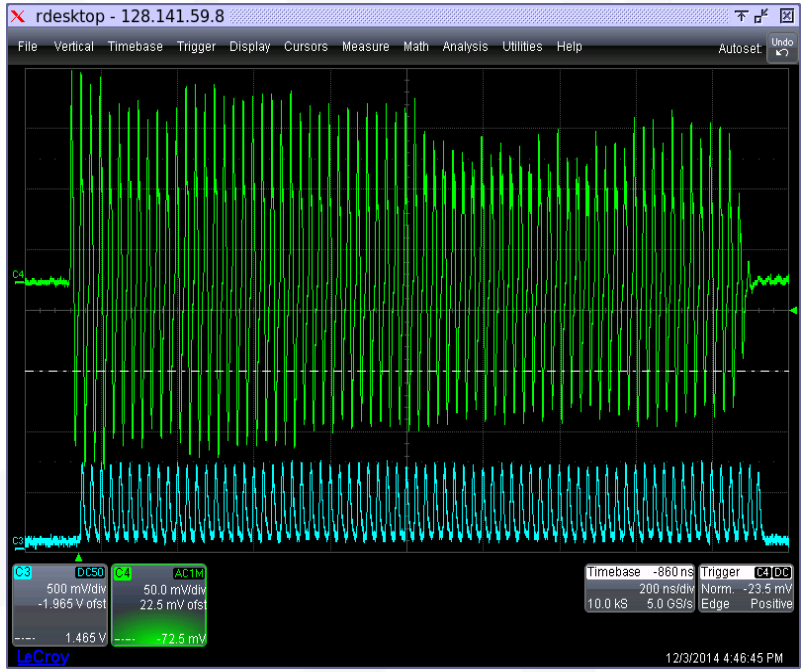


- *Reproducible Orbit with offset similar to the one observed at injection*
  - *No effect due to bunch shortening*
  - *Somehow expected due to 70MHz filter*
- *Slightly larger r.m.s b/b variation than at injection*
- *few bunch measured outside the position limit (+/-4mm)*
  - *Possibly due to ecloud / instabilities*

Doublet bunches at Flat top

Shape of the Signal measured at the entrance of the Normaliser

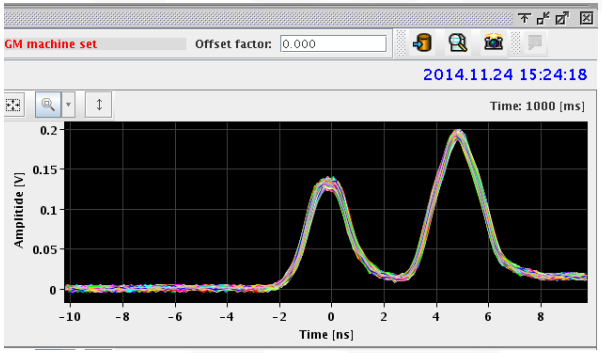




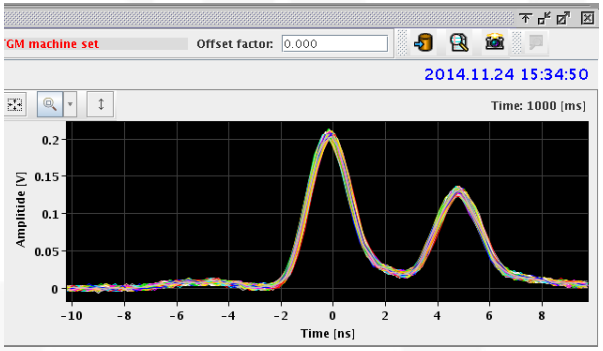
Some 10-30% fluctuations in the doublet bunch intensities over the train

Unbalanced Doublet bunches

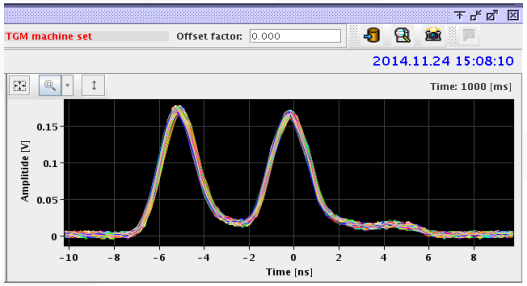
- At 26GeV – 72 Doublet bunches @ 25ns
- 1000 turns acquisition 560ms after injection
- BPM in High sensitivity
- Tests done with and without vertical bump in 515



Unbalanced -/+



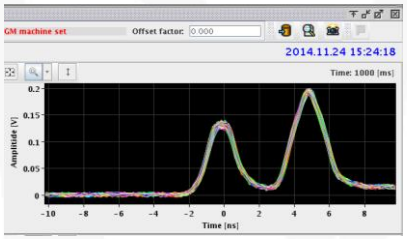
Unbalanced +/-



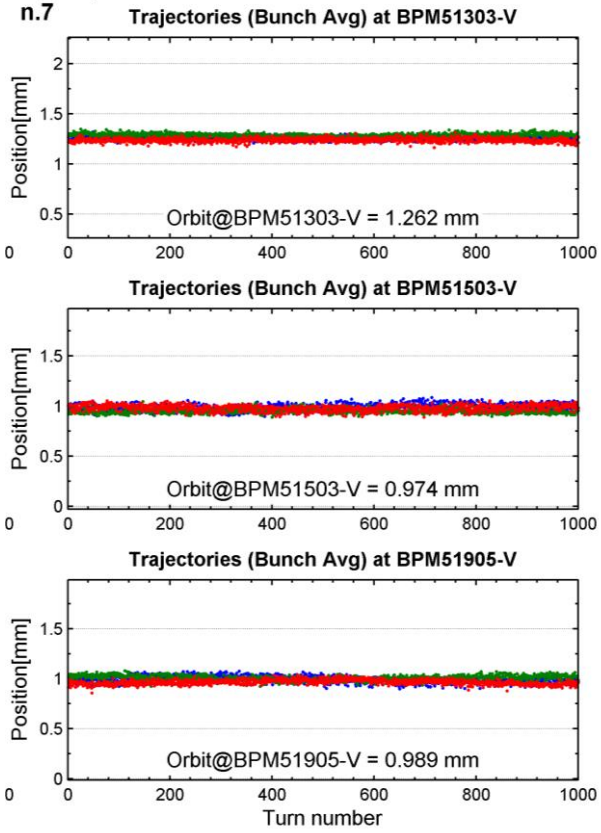
Doublet bunches at injection

- At 26GeV – 72 Doublet bunches @ 25ns
- 1000 turns acquisition 560ms after injection
- BPM in High sensitivity

Unbalanced -/+

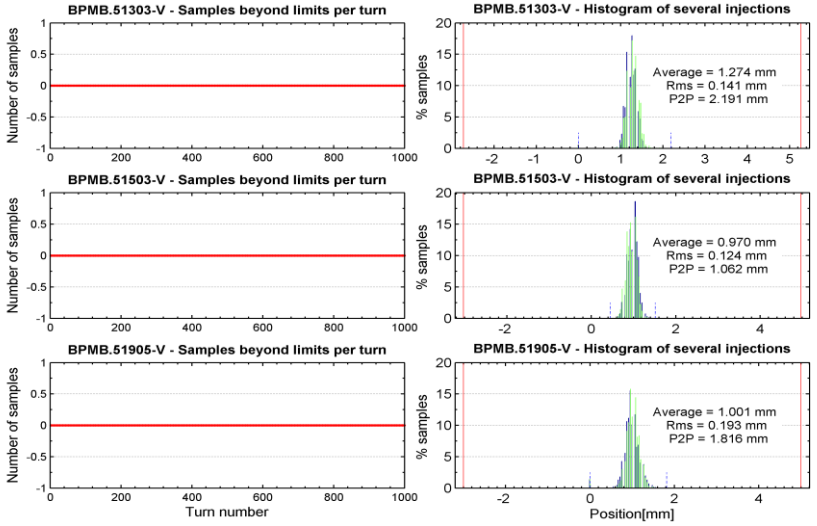


as.Setup n.7



	BPMB.51303-V			BPMB.51503-V			BPMB.51905-V		
	Orbit	Rms	P2P	Orbit	Rms	P2P	Orbit	Rms	P2P
Inj. N.1	1.260	0.127	2.093	0.989	0.123	0.966	0.994	0.198	1.766
Inj. N.3	1.287	0.152	2.191	0.951	0.122	1.062	1.008	0.187	1.816
Inj. N.4	1.239	0.165	2.093	0.981	0.129	1.110	0.966	0.221	1.816
AVERAGE	1.262	0.148	2.126	0.974	0.125	1.046	0.989	0.202	1.799

Meas.Setup n.7

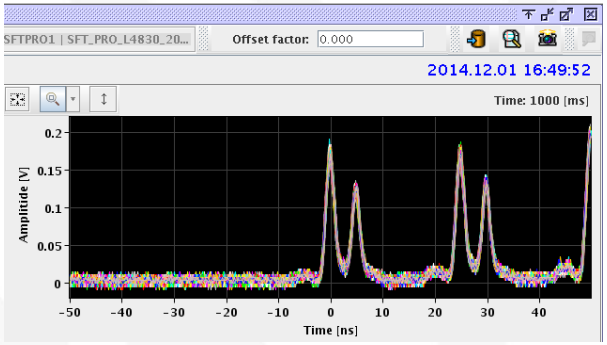


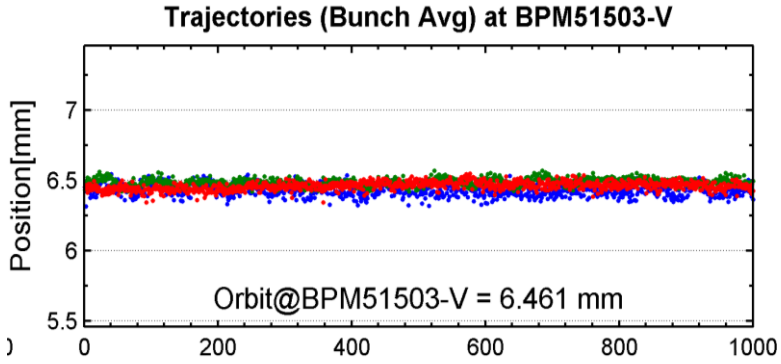
Smaller Offset, r.m.s and P2P variations as expected

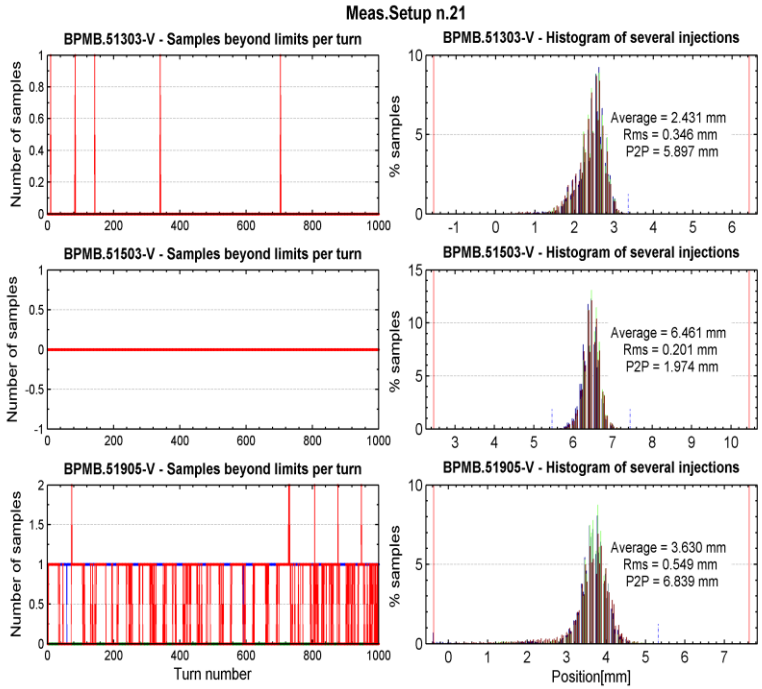
Doublet bunches at injection

- At 26GeV – 72 Doublet bunches @ 25ns
- 1000 turns acquisition 1s after injection
- BPM in High sensitivity
- Vertical offset in 515

Unbalanced +/-





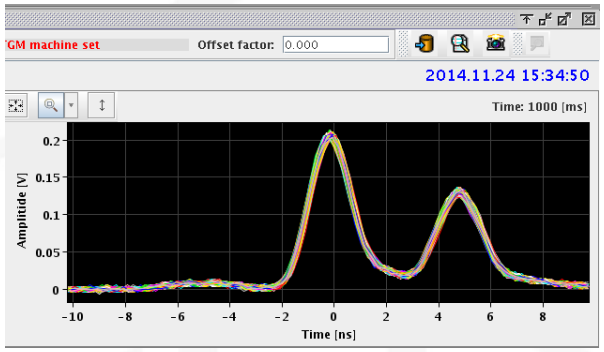


	BPMB.51303-V			BPMB.51503-V			BPMB.51905-V		
	Orbit	Rms	P2P	Orbit	Rms	P2P	Orbit	Rms	P2P
Inj. N.1	2.449	0.337	3.106	6.434	0.206	1.821	3.627	0.591	6.685
Inj. N.2	2.448	0.317	2.288	6.487	0.186	1.723	3.672	0.408	4.547
Inj. N.3	2.396	0.379	5.897	6.461	0.207	1.923	3.592	0.621	6.247
AVERAGE	2.431	0.344	3.764	6.461	0.200	1.822	3.630	0.540	5.826

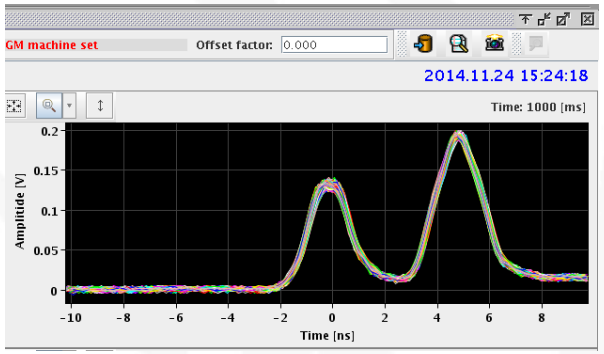
Larger Offset, r.m.s and P2P variations as expected

Doublet bunches at injection

Unbalanced +/-



Unbalanced -/+



	Drift due to doublet	Drift due to doublet
	Unbalanced beam (1st >> 2nd)	Unbalanced beam (1st << 2nd)
BPMB.51303-V	1.686 mm	-0.807 mm
BPMB.51503-V	2.183 mm	-0.215 mm
BPMB.51905-V	3.263 mm	-1.009 mm

- *Offset similar to what was simulated*
- *Larger noise for unbalanced Doublet +/-*
  - *More sensitive due to the shape of the signal*
  - *Unbalanced Doublet -/+ gives lower fluctuations than normal Doublet*

Summary plot